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AUSTRALIA

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ORIGINAL

PROVISIONAL SPECIFICATION

EXHAUST GAS TREATMENT METHOD AND DEVICE

The invention is described in the following statement:

EXHAUST GAS TREATMENT METHOD AND DEVICE

Introduction

This invention relates to the treatment of oxides of nitrogen within the exhaust gas emissions of internal combustion engines, and in particular to a method of operating an internal combustion engine to allow such treatment.

The recent and future introduction of increasingly strict internal combustion engine emissions legislation around the world, particularly as this relates to automotive vehicles, has resulted in increasing pressure on engine and vehicle manufacturers to reduce engine emissions, particularly hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) emissions. These emissions are generally treated by a catalytic converter in the exhaust system of the engine, which is intended to convert these potentially harmful gases into preferred substances such as carbon dioxide, nitrogen, oxygen, and water.

NOx emissions present particular challenges for engine and vehicle manufacturers in that typicalcatalytic converters have been found to be less effective when the engine is operating under lean burn conditions. This is particularly a problem in engines which derive efficiency advantages from lean burn operation, and in particular, stratified charge engines, such as some of those incorporating the Applicant's dual fluid fuel injection system.

Dual fluid fuel injection systems typically utilise compressed gas during each injection event to entrain and atomise a metered quantity of fuel for delivery into the combustion chambers of an internal combustion engine. The Applicant has developed such fuel injection systems and one version thereof is described in the Applicant's U.S. Patent No. 4934329, the details of which are incorporated herein by reference. Generally, a source of compressed gas, for example an air compressor, is required for these fuel injection systems to operate satisfactorily. The term "air" is used herein to refer not only to atmospheric air, but also to other gases including air and exhaust gas or fuel vapour mixtures. In operation, such dual fluid fuel injection systems typically rely on the existence of a differential pressure between the fuel which is metered for subsequent delivery and the compressed gas, typically air, which is used to deliver the fuel to the engine. In this regard, it is normal that the fuel pressure is slightly higher than the air pressure such that the fuel may be metered into a volume of compressed gas in a manner akin to that described in U.S. Patent No. 4934329.

Prior Art

Various methods of engine operation and engine exhaust systems have been proposed to overcome the problem of NOx emissions. One known example, set out in US patent no 5433074, proposes the use of a specific NOx adsorbent layer in the catalyst. This layer or coating is intended to absorb NOx emissions under typical low NOx conversion conditions (that is, during lean burn operation of the engine) and release the absorbed NOx under typical high NOx conversion conditions (that is, during richer than stoichiometric operation of the engine). The adsorbent layer is a NOx adsorbent material including Barium (Ba).

The system proposed in this patent has a number of potential disadvantages. The Ba adsorbent layer can also adsorb sulphuric elements where these are present, and will adsorb such sulphuric elements in preference to the desired NOx adsorption. As such, where sulphur is present in the fuel, this can cause "clogging" of the Ba adsorbent, reducing its effectiveness in its role as an NOx adsorbent. Fuel economy can also be compromised by the requirement of periodic "flushing" of the system with a rich air-fuel mixture. Further, in order to ensure effective operation of the system, additional sensors may be required to provide feedback to the engine controller for the purpose of determining whether "flushing" is required. The system may also be temperature sensitive, and damage to the adsorbent layer may occur at temperatures above 750 degrees Celsius, whilst effective operation of the storage capacity may be limited to a window of around 300 to 550 degrees Celsius.

Summary of the Invention

It is the aim of this invention to provide an alternative NOx treatment method and device, which overcomes at least some of the disadvantages of the prior art systems.

In accordance with a first aspect of the present invention, there is provided a method of treating NOx emissions in the exhaust gas of an internal combustion engine having catalyst means capable of treating NOx treating first catalytic converter, the method comprising the steps of: operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions; the first mode of operation including operating the engine with a lean air-fuel ratio; and the second mode of operation including operating the engine with a stoichiometric air-fuel ratio.

Conveniently, the catalyst means includes a first catalyst converter arranged in an exhaust system of the engine. Preferably, the first set of conditions include exhaust gases with a lean air-fuel ratio and lower relative temperatures. Conveniently, the second set of conditions include exhaust gases with a stoichiometric air fuel ratio. In many cases, the second.set of conditions will include higher relative exhaust gas temperatures. Preferably, the exhaust gas temperatures produced by the engine whilst it operates under the first mode of operation are in the range 200 to 400 degrees Celsius. Preferably, the exhaust gas temperatures produced by the engine whilst it operates under the second mode of operation are greater than 200 degrees Celsius, and typically the exhaust gas temperatures are greater than 400 degrees Celsius. Preferably the relevant exhaust temperature is that of the exhaust gas at the first catalytic converter. Preferably the temperature of the exhaust gas is controlled by way of appropriate operation of the engine to ensure effective operation of the first catalytic converter under the first mode of operation. Preferably the temperature of the exhaust gas in this case is controlled to be within the range 200 to 400 degrees Celsius. Preferably the temperature of the exhaust gas is controlled controlled by way of appropriate operation of the engine to ensure effective operation of the first catalytic converter under the second mode of operation. Preferably the temperature of the exhaust gas in this case is to be greater than approximately 400 degrees Celsius. Conveniently, the operation of the engine is controlled during the first mode so as to generate the exhaust gas emissions having characteristics that can support acceptable levels of NO_x conversion within the first catalytic converter.

Preferably the first catalytic converter a combination of Pt (or Pd), Rh and Ba elements. Preferably, the first catalytic converter comprises a greater proportion of Pt (ie: it is "Pt rich") than would be expected in a typical three way catalyst. Preferably the ratio of Pt to Rh in the first catalytic converter is 10:1. Preferably, the proportion of Ba in the first catalyst converter is relatively low as compared to the proportions of Pt and Ph. Preferably, the operation of the engine during the first mode is controlled so as to promote a selective catalyst reduction process at the first catalytic converter which is normally not supported during lean burn operation. The composition of the first catalytic converter is preferably slightly different to that expected in a typical three way catalyst comprising pt (or

Pd) and Rh. Conveniently, the subtle difference in the composition of the first catalyst converter together with the promotion of the first set of conditions during the first mode enable the achievement of higher NO_x emission efficiencies than would otherwise be expected form a typical three way catalyst during the said first mode of operation.

Conveniently, the operation of the engine is controlled during the second mode so as to promote high NO_x conversion efficiency levels within the first catalytic converter.

Preferably a temperature sensing device is provided in the exhaust system of the internal combustion engine, and the output from the temperature sensing device is used to determine the mode of operation of the internal combustion engine. Preferably a sensed temperature of between 200 and 400 degrees Celsius will result in operation of the engine under the first mode of operation. Preferably a sensed temperature of greater than 400 degrees Celsius will result in operation of the engine under the second mode of operation. This latter mode of operation will typically equate to high engine load operating conditions wherein the temperatures of the exhaust gas are usually higher than during lean burn operation.

Preferably the first catalytic converter is provided in the exhaust system at a position sufficiently downstream of the internal combustion engine that the exhaust gas is allowed to cool somewhat before entering the first catalytic converter.

Preferably a second catalytic converter is provided in a close coupled configuration with the internal combustion engine for the purpose of oxidising hydrocarbon and carbon monoxide emissions in the engine exhaust gases. Preferably the first catalytic converter is a three way catalyst. Conveniently, the engine is direct injected. Preferably, fuel injection to the engine is effected by way of a two fluid fuel injection system.

According to a second aspect of the present invention, there is provided a device for use with the above method.

Preferred Embodiment of the Invention

It will be convenient to further describe the invention with respect to the accompanying drawings that assist in describing various possible arrangements of the present invention. Other arrangements of the invention are however

possible, and consequently, the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

In the drawings:

Figure 1 is a schematic partial cross-sectional view of an internal combustion engine having a dual fluid fuel injection system operatively arranged with respect thereto;

Figure 2 is a partial cross-sectional view of one form of a fuel metering and injector rail unit;

Figure 3 is a schematic layout of an internal combustion engine and exhaust system according to an embodiment of the present invention; and

Figure 4 is a graph showing engine load against engine speed for an engine operating in accordance with an embodiment of the present invention.

The Applicant's two fluid fuel injection system will first be described in some detail with reference to Figures 1 and 2, and then a description of the application of the present invention to an engine with that fuel injection system will follow with particular reference to Figures 3 and 4. It is to be understood that use of the present invention will not in any way be limited to engines with the described fuel supply system, which is set out for the purposes of exemplification only.

Figure 1 shows a direct injected four stroke internal combustion engine 20 comprising a fuel injection system, the engine 20 having an air intake system 22, an ignition means 24, a fuel pump 23, and fuel reservoir 28. An air compressor 29 is operatively arranged with respect to the engine 20 and typically driven off the engine crankshaft 33 or other drive-train by way of a suitable belt (not shown). Mounted in the cylinder head 40 of the engine 20 is a fuel and air rail unit 11. The fuel pump 23 draws fuel from the fuel reservoir 28 which is then supplied to the fuel and air rail unit 11 though a fuel supply line 55. Conventional inlet and exhaust valves 15 and 16 are also mounted in the cylinder head 40 in the known manner together with conventional cam means 17 for actuating the valves 15, 16. The valves 15, 16 are arranged to open and close corresponding inlet and exhaust ports 18 and 19 for admission of fresh air and the removal of exhaust gases from the engine cylinder in the known manner.

Referring now to Figure 2, there is shown in detail a fuel and air rail unit 11

which, whilst being different in design from that shown in Figure 1, shares all the same components thereof. The fuel and air rail unit 11 comprises a fuel metering unit 10 and an air or delivery injector 12 for the or each cylinder of the engine 20. The fuel metering unit 10 is commercially available and requires no detailed description herein. Suitable ports are provided to allow fuel to flow through the fuel metering unit 10 and a metering nozzle 21 is provided to deliver fuel to a passage 90 and thence to the air injector 12. The body 8 of the fuel and air rail unit 11 may be an extruded component with a longitudinally extending air duct 13 and a fuel supply duct 14.

As best seen in Figure 1, at appropriate locations, there are provided connectors and suitable ducts communicating the rail unit 11 with air and fuel supplies: air line 49 communicating air duct 13 with the air compressor 29; air line 53 providing an air outlet which returns air to the air intake system 22; and fuel line 52 communicating the fuel supply duct 14 the fuel reservoir 28 providing a fuel return passage. The air duct 13 communicates with a suitable air regulator 27 which regulates the air pressure of the compressed air provided by the air compressor 29 to the air duct 13.

Referring again to Figure 2, the air injector 12 has a housing 30 with a cylindrical spigot 31 projecting from a lower end thereof, the spigot 31 defining an injection port 32 communicating with passage 90. The injection port 32 includes a solenoid operated selectively openable poppet valve 34 operating in a manner similar to that as described in the Applicant's U.S. Patent No. 4934329, the contents of which are hereby incorporated by reference. As best seen in Figure 1, energisation of the solenoid in accordance with commands from an electronic control unit (ECU) 100 causes the valve 34 to open to deliver a fuel-gas mixture to a combustion chamber 60 of the engine 20. However, it is not intended to limit the valve construction to that as described above and other valves, for example, pintle valve constructions, could be employed. The electronic control unit (ECU) 100 typically receives signals indicative of crankshaft speed and airflow from suitably located sensors within the engine (not shown). The ECU 100, which may also receive signals indicative of other engine operating conditions such as the engine temperature, ambient temperature and battery voltage (not shown), determines from all input signals received the quantity of fuel required to be ~~delivered to each of the cylinders of the engine 20. As alluded to hereinbefore,~~

this general type of ECU is well known in the art electronically controlled fuel injection systems and will not be described herein further detail.

The opening of each injector valve 34 is controlled by the ECU 100 via a respective communicating means 101 in timed relation to the engine cycle to effect delivery of fuel from the injection port 32 to a combustion chamber 60 of the engine 20. By virtue of the two fluid nature of the system, fuel is delivered to the cylinder entrained in a gas. The passage 90 is in constant communication with the air duct 13 via the conduit 80 as shown in Figure 2 and thus, under normal operation, is maintained at a substantially steady air pressure. Upon energisation of the solenoid of the air injector 12, the valve 34 is displaced downwardly to open the injection port 32 so that a metered quantity of fuel delivered into the air injector 12 by the fuel metering unit 10 is carried by air through the injection port 32 into the combustion chamber 60 of a cylinder of the engine 20.

Typically, the air injector 12 is located within the cylinder head 40 of the engine 20, and is directly in communication with the combustion chamber 60 defined by the reciprocation of a piston 61 within the engine cylinder. As above described, when the injection port 32 is opened and the air supply available via the conduit 80 is above the pressure in the engine cylinder, air will flow from the air duct 13 through the passage 80, passage 90 and, entrained with fuel, injection port 32, into the engine combustion chamber 60.

Turning now to Figure 3, a new set of reference numerals have been adopted due to the schematic nature of this illustration. The features illustrated include engine 200, fuel intake 202, air intake 204, close coupled catalytic converter 206, main catalytic converter 208 and external exhaust outlet 210. A temperature sensor 214 is located adjacent the entry to the main catalytic converter 208.

As is usual in the operation of engine systems of this type, fuel and air are taken in through their respective intakes 202, 204. Combustion then takes place in the engine 200, and exhaust gases pass out of the engine 200. In this Figure, there is illustrated an optimal coupled catalytic converter 206 through which the exhaust gases may pass immediately as they leave the combustion chamber of the engine 200. Exhaust gases then travel along exhaust pipe 212 to the main catalytic converter 208, and subsequently out the external exhaust outlet 210. ~~The catalytic converter 208 may for example be an underbody catalyst arranged~~

to be a specified distance downstream of an exhaust port (not shown) of the engine.

The engine operation includes two major modes, and two transitional modes (although the engine need not necessarily operate under these modes at all times and other modes of operation are possible). Preferred modal operation of the engine is best shown in Figure 4.

In lean operation mode (indicated by reference numeral A), the engine operates in lean burn mode, with a stoichiometric coefficient of greater than 1.3. (ie: The stoichiometric coefficient is 1 for a stoichiometric air-fuel ratio, greater than 1 for a lean air-fuel ratio, and less than 1 for a rich air-fuel ratio.) In the stoichiometric ratio mode (indicated by reference numeral C), the air-fuel ratio is maintained at stoichiometric and the stoichiometric coefficient is 1.

Engine operation is preferred in either one of these major modes of operation, however, a first transition mode (indicated by reference numeral B) may be required when transferring between lean mode A and stoichiometric mode C. A transitional peak mode (indicated by reference numeral D) may also be provided, and is used for specific high load operation for generally temporary operation using a fuel rich air-fuel ratio (stoichiometric coefficient less than 1).

During the lean mode operation A, the temperature of the exhaust gas at the entry to the main catalyst 208 is preferably in the range of 200 to 400 degrees Celsius. In stoichiometric operation C, the temperature of the exhaust gas at the entry to the main catalyst 208 is typically above 400 degrees Celsius. Conveniently, in this latter mode of operation, the engine can be controlled by way of a dual injection strategy such as that disclosed in the Applicants' International Patent Application No. PCT/AU98/01004, the contents of which are included herein by reference.

Control of the system can be performed in two different ways. Firstly, the mode of the engine can be controlled on the basis of the known or estimated temperature of the exhaust gas. In this case, a sensor 214 can provide information to the engine management system for the purposes of controlling the engine operation appropriately. Secondly, the temperature of the exhaust gas can be controlled to fit the mode of operation under which the engine is currently operating or is desired to operate. Of course, a combination of these two methods of control can also be used.

The main catalytic converter 208 is a three way converter which catalytically treats hydrocarbons, carbon monoxide gases and nitrous oxides. The Applicant has found that a Pt-Rh-Ba catalytic converter is particularly useful, and specifically has found that the characteristics of a Johnson-Matthey development version D268/JM370 provides especially good results. This catalytic converter has a ratio of Pt:Rh of 10:1 in the catalytically active part of the converter. The catalytic converter also has a small proportion of Ba therein.

It is believed that the operation of the engine 200 in mode A so as to promote exhaust gases with a lean air fuel ratio and relatively lower gas temperatures supports a selective NO_x reduction process that is not typically supported by a normal 3 way catalyst. It is further believed that this selective NO_x reduction process is further supported by the presence of a Pt rich catalytic converter, and perhaps still further by the presence of some Ba on the converter. This selective NO_x reduction process promotes the reduction of NO_x emissions down to the less harmful components such as N_2O, N_2 and O_2.

In mode C, the engine 200 is controlled in such a way to take advantage of the high conversion efficiencies that the catalyst converter 208 can provide under stoichemetric operating condition, these conditions being synonymous with higher exhaust gas temperatures and higher load operating points.

The use of the close coupled catalytic converter 206 as illustrated in Figure 3 can increase the effectiveness of the overall emission reduction process by oxidising hydrocarbon and carbon monoxide emissions under conditions which produce lower temperature exhaust gases (for example, the lean mode operation) as the temperature of the exhaust gases immediately adjacent the engine are significantly greater than downstream at the main catalytic converter 208. The reason this is beneficial is that these emissions (hydrocarbons and carbon monoxide) are more efficiently catalysed at higher temperatures. The combined lean stratified and stoichiometric NO_x treatment according to the present invention enables some of the potential problems of prior art systems and in particular NO_x storage type methods to be avoided.

The method according to the present invention is applicable to both two stroke and four stroke engines incorporating direct injection systems and particularly those operation with a dual fluid fuel injection system. Modifications

and variations as would be deemed obvious to the person skilled in the art are included within the ambit of the present invention.

DATED this 8th Day of September, 1999

ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED

WATERMARK PATENT & TRADEMARK ATTORNEYS
4TH FLOOR "DURACK CENTRE"
263 ADELAIDE TERRACE
PERTH WA 6000

Fig 1.

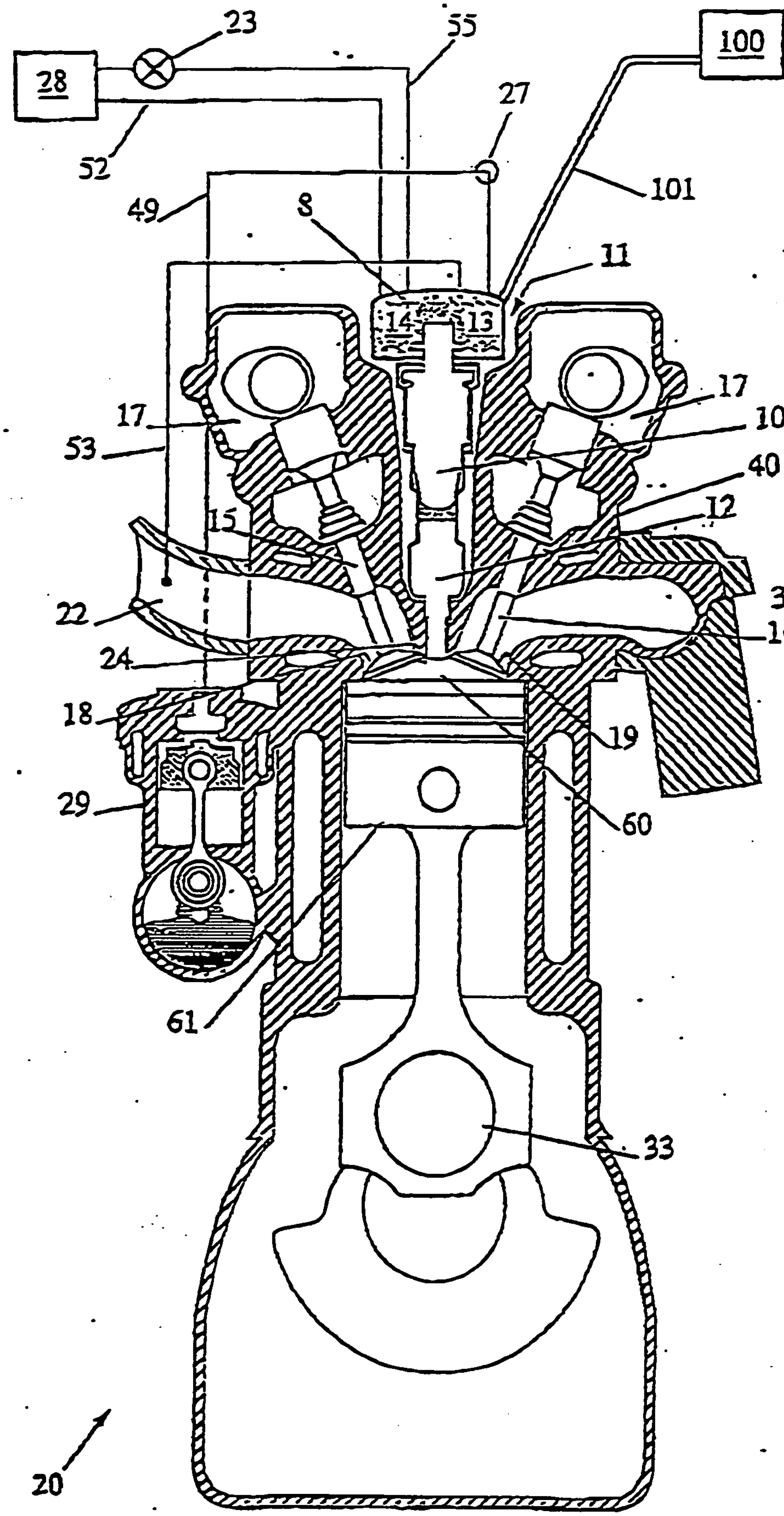

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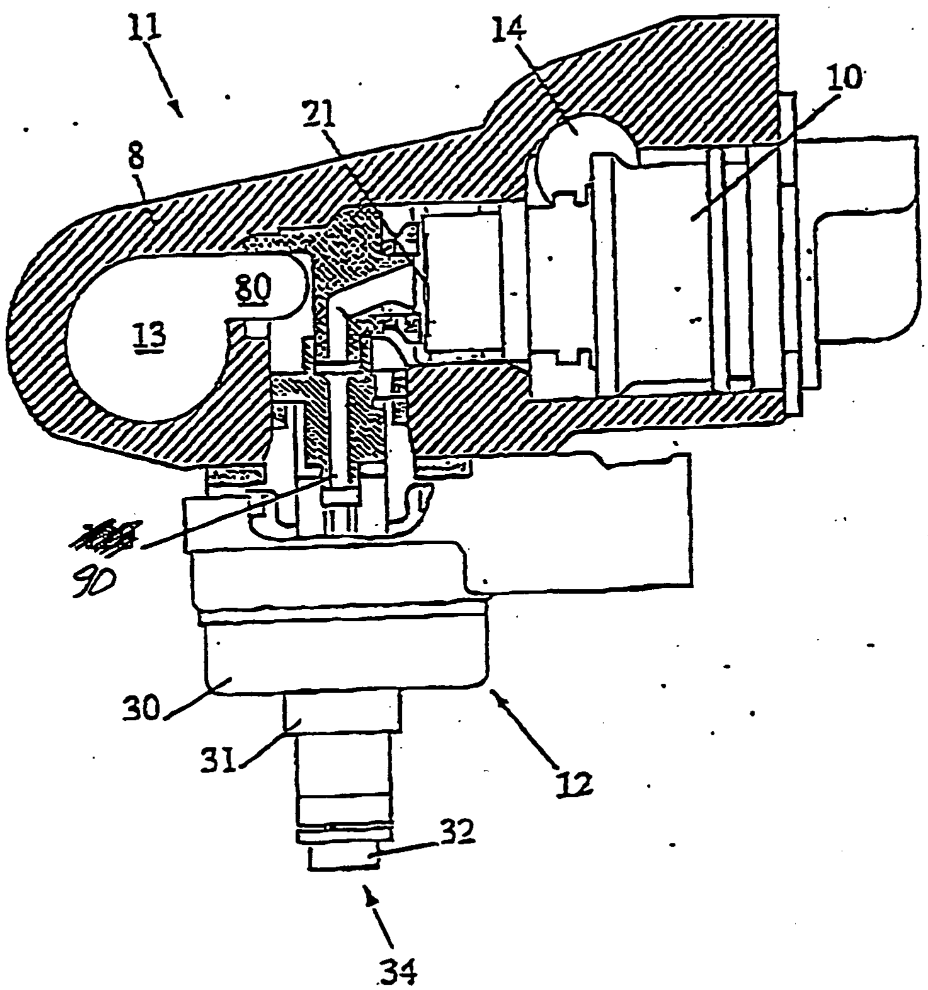
Fig 2.



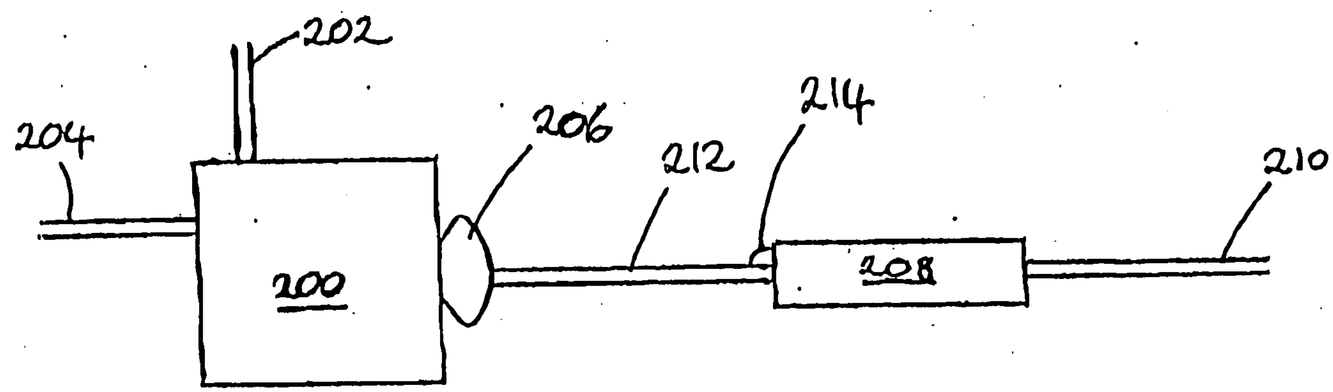


FIGURE 3

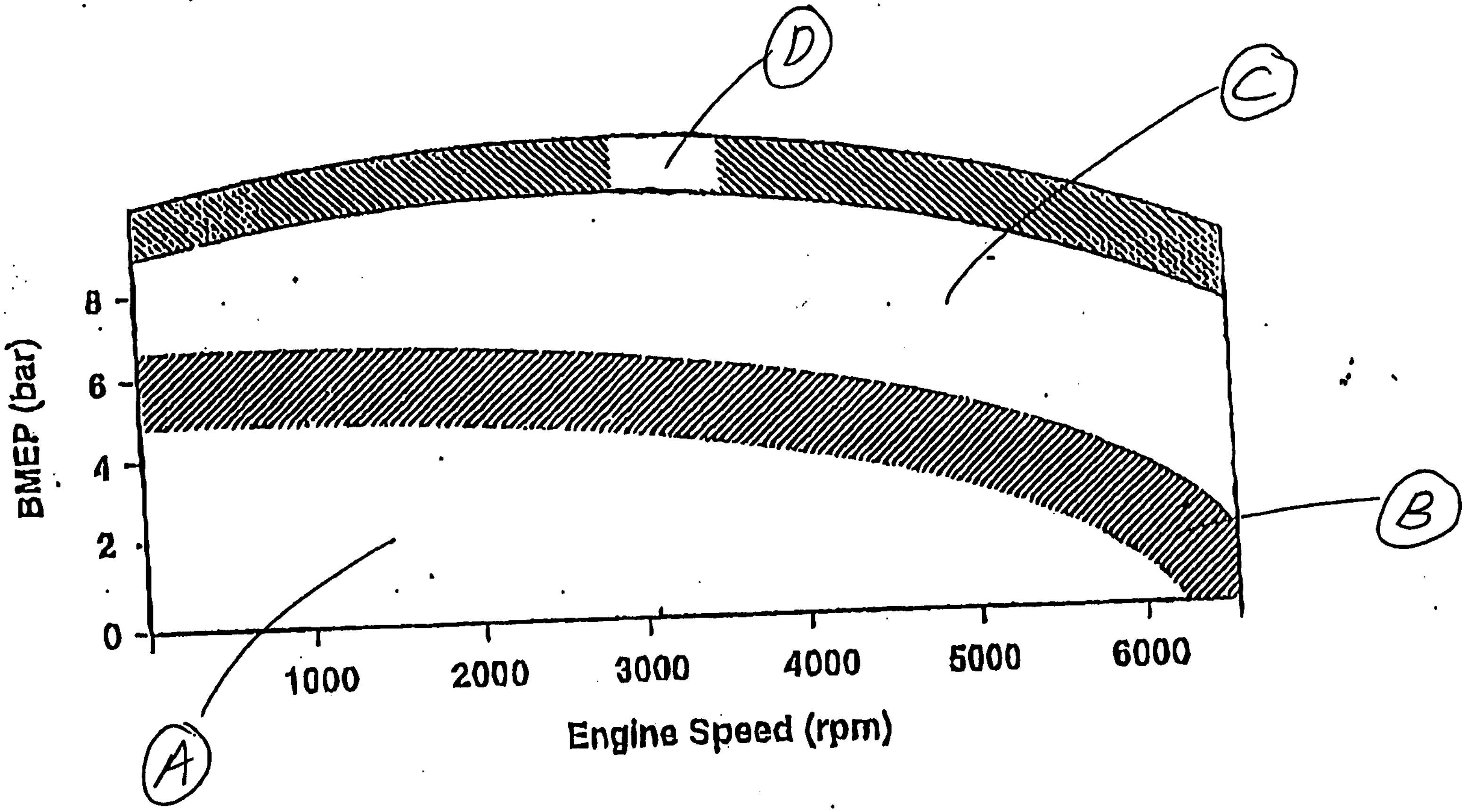

D
C
B
A
8
6
4
2
0
BMEP (bar)
1000
2000
3000
4000
5000
6000
Engine Speed (rpm)

FIGURE 4